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Effect of Certain Preharvest Factors on Yield and Quality of Raw and Processed Tomatoes¹

By A. A. KATTAN,² F. C. STARK, and A. KRAMER, *University of Maryland, College Park, Maryland*

TOMATOES constitute the most important processing crop in the Middle Atlantic states. In the past few years a reduction in production of tomato products in the Middle Atlantic area was matched by an increase in California production. Perhaps this trend could be arrested if there were a better understanding of the effect of preharvest factors on the yield and quality of tomato products. A recent survey indicated that the two major factors of quality are color and firmness. In the Maryland area the bulk of the tomato crop ripens during the month of August when rather high temperatures prevail—a factor that limits the maximum development of lycopene in the fruits (2, 16), and which may be also limiting to other quality factors. There are also a few indications in the literature that the macro- and micro-nutrients may have an effect on the quality of the tomato fruit (6, 7, 8).

In the spring of 1952 a three-year program was initiated to investigate the effect of the various preharvest cultural practices on the yield and quality of tomatoes under the climatic conditions prevailing in the Middle Atlantic area. The following factors were under study: (A) Effect of variety; (B) Effect of soil fertilization; (C) Effect of foliar nutrient sprays; (D) Effect of time of planting.

MATERIALS AND METHODS

The experimental plots for the variety and the foliar nutrient spray studies were located on sandy loam soil at the Vegetable Research farm at Salisbury, Maryland. Plots for the soil fertilization and time-of-planting studies were located on silt loam soil at the Plant Research Farm near College Park. In the soil fertilization and the foliar nutrient spray tests the Chesapeake variety (21) was used; both Chesapeake and Rutgers were used in the time-of-planting test. All cultural practices used, other than those under investigation, were in accord with the recommendations of the Experiment Station for the specific area.

Plots located at Salisbury consisted of 20 plants per plot; at College Park each plot consisted of ten plants. In each of the field studies, the plots were randomized in quadruplicate in complete blocks, and were harvested at weekly intervals for recording yields. Weekly samples from the College Park plots and biweekly samples from the Salisbury plots were brought into the processing laboratory

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²Present address: Department of Horticulture, University of Arkansas, Fayetteville, Arkansas.

at College Park for canning and quality determinations, both conducted within 24 hours from the time of harvest. Each of these samples consisted of one-half bushel of marketable tomatoes and represented the four replicates of a specific treatment. The fruits were washed and a random sample of ten fruits was taken for firmness rating of 1-10. Each lot of fruits was then separated into two sub-lots. One was juiced and the difference between the weights of the fruits and the juice determined the waste. A sample of the raw juice was obtained for quality determinations, and the rest of the juice heated to a closing temperature of 180 degrees F, canned in No. 1 cans and processed for 20 minutes at 212 degrees F. The other half of each lot of fruits was weighed, scalded for one minute in boiling water, cooled, peeled and trimmed and the percentage of trimming loss was calculated. The tomatoes were then placed in No. 2 cans, exhausted to a closing temperature of 180 degrees F and processed for 25 minutes at 212 degrees F. All canned samples were prepared in triplicate. The following quality measurements were determined:

Raw product: Firmness, waste in pulping, trimming loss, color, pH, viscosity, soluble solids, and total solids.
Canned juice: Color, pH, soluble solids, viscosity, separation, and flavor.
Canned tomatoes: Color, drained weight, wholeness, firmness and flavor.

Color was determined by the use of the Hunter color and color difference meter. The equivalent U. S. color score was calculated from the "a" and "b" Hunter values according to the equation (11): $U. S. \text{ color score} = 32.6 + .682a - 1.678b$. Mavis and Gould (18) suggested the use of the Hunter Lb/a ratio which proved to be superior to the a/b ratio. The exact relationship between the Hunter values and the color score however, should be calculated by multiple correlation which was the basis of calculation of the equation (11) used in this study. Relative viscosity was determined with the Stormer viscosimeter, using a 70 gm. weight. For determining separation, 200 ml. of canned juice were placed into a 500 ml. graduate cylinder and after 24 hours at room temperature, the percentage of clear supernatant liquid (serum) was calculated. Wholeness, firmness, and flavor were determined by the use of a sensory panel, who scored each factor on a 1-10 scale, with 1 indicating poorest, and 10 highest quality.

RESULTS AND DISCUSSION

Effect of Variety:—In one test 13 varieties and seven STEP³ lines were under study and the results are presented in Tables 1 and 2. Rutgers, the leading variety of the eastern grown tomatoes, was out-yielded only by STEP 197. Chesapeake and Manalucie were the only two varieties with yields significantly lower than Rutgers. The lower yield of Chesapeake as compared with Rutgers was expected when

Table 1.—Yield and quality of raw tomatoes of 20 varieties grown at Salisbury, Md., 1954. (Sampling dates: August 5, August 18, September 2, September 16.)

Variety	Yield (tons per acre)	Firm- ness 1-10	Per- cent- age of waste	Percent- age of trim- ming loss	Color (U.S.)	pH	Viscosity (seconds)	Percent- age of soluble solids	Percent- age of total solids
1. Wiltmaster.....	7.58	7.4	35.1	16.9	28.9	4.37	14.3	6.2	6.96
2. Delaware 4E....	8.44	7.6	29.9	16.4	29.9	4.37	13.9	6.0	6.79
3. W-R Brookston..	9.61	6.9	27.8	18.6	30.6	4.38	16.1	5.8	6.67
4. Rutgers.....	7.89	6.7	32.1	16.5	30.5	4.41	14.5	6.2	6.77
5. Queens.....	8.64	7.2	31.4	16.9	29.9	4.42	15.7	6.0	6.79
6. N. Imp. Garden State.....	9.46	7.6	31.1	18.8	29.7	4.41	14.6	5.7	6.50
7. Stokescross 4....	7.65	7.3	30.2	18.8	29.5	4.38	13.5	6.0	6.63
8. Valiant.....	8.16	7.1	27.6	20.0	28.1	4.38	13.8	5.8	6.64
9. Stokescross 5....	8.07	7.3	31.8	18.3	28.9	4.26	15.0	5.8	6.47
10. Master Marglobe	6.87	7.5	30.0	15.8	29.4	4.27	15.0	6.0	6.88
11. Chesapeake.....	4.13	6.8	30.8	18.0	27.6	4.43	14.5	6.0	6.63
12. Big Boy.....	7.03	8.0	29.8	18.4	28.1	4.40	14.3	6.2	6.80
13. Manalucie.....	4.72	7.4	31.7	15.8	27.5	4.41	14.5	6.3	6.95
14. STEP 174.....	9.58	7.1	31.5	17.9	30.0	4.33	15.5	5.8	6.35
15. STEP 193.....	7.68	6.4	29.4	22.4	28.8	4.38	15.1	5.7	6.29
16. STEP 197.....	10.00	7.3	26.4	17.2	27.8	4.25	14.4	5.5	6.29
17. STEP 202.....	6.77	8.0	29.9	18.0	27.3	4.20	12.9	6.2	6.83
18. STEP 207.....	7.08	7.1	31.6	21.1	28.7	4.35	15.9	5.7	6.34
19. STEP 215.....	8.97	6.8	26.0	21.3	29.0	4.30	15.0	6.0	6.42
20. Md. 16.....	7.93	7.0	26.9	18.4	29.6	4.35	14.2	5.9	6.60
L.S.D. @ 5%.....	1.81	n.s.	4.4	3.0	1.9	0.08	n.s.	0.4	0.40

Table 2.—Quality of processed tomatoes and tomato juice of 20 varieties grown at Salisbury, Md., 1954.

Variety	Canned juice						Canned tomatoes				
	Color U.S.	pH	Per- cent- age of solu- ble solids	Vis- cosity (sec- onds)	Per- cent- age of sepa- ration (1-10)	Flavor	Color (U.S.)	Per- cent- age of drained weight	Whole- ness (1-10)	Firm- ness (1-10)	Flavor (1-10)
1. Wiltmaster....	25.0	4.31	6.4	13.3	1.9	8.6	25.4	66.2	3.8	4.0	6.3
2. Delaware 4E....	25.9	4.33	6.4	12.8	2.1	7.2	24.8	67.9	4.8	4.5	5.6
3. W-R Brookston..	26.8	4.34	6.1	13.8	1.4	6.5	25.7	67.0	4.8	4.8	6.1
4. Rutgers.....	26.8	4.38	6.3	13.7	1.5	7.2	25.9	62.9	4.0	4.0	6.7
5. Queens.....	26.8	4.39	6.5	13.8	1.9	7.6	25.5	67.0	6.0	5.5	5.2
6. N. Imp. Garden State.....	25.2	4.29	6.1	13.9	1.6	7.6	25.3	69.3	4.8	4.0	4.7
7. Stokescross.....	25.5	4.35	6.3	12.5	2.1	6.7	23.9	68.8	5.5	5.2	5.9
8. Valiant.....	25.3	4.37	6.3	12.4	3.2	7.4	23.7	72.0	6.5	6.2	5.6
9. Stokescross.....	25.4	4.23	6.1	13.3	2.4	6.9	24.9	65.9	5.5	4.2	6.1
10. Master Mar- globe.....	25.1	4.23	6.5	13.9	1.0	7.2	25.4	64.4	5.0	4.2	6.6
11. Chesapeake.....	23.8	4.37	6.3	12.9	1.6	7.6	22.6	69.9	4.8	4.2	5.3
12. Big Boy.....	24.6	4.34	6.4	13.6	2.1	7.2	23.2	66.7	5.2	5.0	6.7
13. Manalucie.....	23.3	4.39	6.7	13.8	1.5	5.9	23.0	66.9	4.8	4.5	5.8
14. STEP 174.....	26.4	4.29	6.0	13.5	1.2	6.8	24.7	64.7	5.0	5.0	5.7
15. STEP 193.....	25.4	4.33	5.8	12.4	3.0	6.3	24.7	65.9	5.0	4.2	3.7
16. STEP 197.....	24.1	4.19	5.9	13.2	2.6	4.7	23.2	62.1	3.8	3.5	4.7
17. STEP 202.....	23.3	4.24	6.5	12.6	2.0	6.1	22.2	63.3	5.8	5.0	5.2
18. STEP 207.....	25.1	4.28	6.0	13.2	3.1	6.7	22.9	66.1	5.2	4.5	4.8
19. STEP 215.....	24.8	4.28	6.0	13.8	1.0	6.7	24.2	63.9	4.5	4.5	6.8
20. Md. 16.....	25.3	4.30	6.0	13.1	2.2	6.8	23.0	67.2	5.5	4.8	6.6
L.S.D. @ 5%.....	1.8	0.07	0.4	0.5	n.s.	1.8	2.1	6.4	n.s.	n.s.	n.s.

both are grown on the light sandy loam at Salisbury. This relationship would not be true, however, if both were grown on heavier soils, as will be shown later in the time of planting studies. Chesapeake, which was bred primarily for cracking resistance, is apparently selective for its adaptation to soil type. Examination of the raw product (Table 1) indicated that none of the varieties in this test was higher in color score, pH, soluble solids, or total solids than Rutgers. Valiant and three STEP lines were the only ones to give less waste during pulping than Rutgers. Valiant, however, along with three other STEP lines, required more trimming than Rutgers in preparation for canning of whole tomatoes. No differences were apparent in firmness of the raw fruits.

The data on quality of the canned juice are presented in Table 2. None of the varieties was better in color than Rutgers, with Wiltmaster, Chesapeake, Big Boy, Manalucie, and STEP lines 197, 202, and 215 being somewhat less good in color. Manalucie was the only variety with higher soluble solids as compared with Rutgers. STEP 193 and 197 showed lower percentages of soluble solids. Likewise in the canned juice none of these varieties was lower in acidity than Rutgers. Several varieties were lower in pH, which may create the possibility of reducing the thermal sterilization requirement, resulting in higher color retention. Flavor did not seem to be primarily a function of acidity, a statement found to be in accord with previous findings (20), as may be seen by comparing Manalucie and STEP 197 with Rutgers. Several varieties showed lower viscosity values when compared with Rutgers; none, however, was higher. Tendency toward separation of clear serum seemed to be equal in all varieties. Examination of canned tomatoes indicated no differences in wholeness, firmness, or flavor. The generally low values of wholeness and firmness were expected inasmuch as calcium salts (10) were not added to any of these experimental packs. Rutgers canned tomatoes were not exceeded in color; and in comparison with this variety Valiant, Chesapeake, Big Boy, Manalucie, STEP lines 197, 202, 207, and Md. 16 were inferior. Determinations of drained weight indicated that Rutgers was among the lowest in this respect and was inferior to N. Imp. Garden State, Stokescross 4, Valiant, and Chesapeake.

Another test was conducted at Salisbury to compare Rutgers with nine advanced breeding lines of the Maryland Station. The data obtained from this test are presented in Tables 3 and 4. One line, x-146-1, outyielded Rutgers by five tons per acre and possessed color equivalent to that of Rutgers. Furthermore, this line was consistently low in pH, which may suggest the possibility of using lower heat sterilization, resulting in subsequent better color. It was, however, lower than Rutgers in both soluble and total solids. Except for pH, soluble and total solids, all of the lines studied were equal to Rutgers in quality.

Effect of Soil Fertilization:—In a previous unpublished investigation it was found that varying the levels of nitrogen, phosphorus and potassium did not exert any effect on the quality of the raw or the canned product other than on the separation of the clear serum

Table 3.—Yield and quality of raw tomatoes of nine advanced breeding lines at Salisbury, Md., 1954. (Sampling dates: August 11, August 26, September 2.)

Line	Yield (tons/acre)	Firm- ness (1-10)	Percent- age of waste	Percent- age of trim- ming loss	Color U.S.	pH	Viscosity (seconds)	Percent- age of soluble solids	Percent- age of total solids
X-67-1	12.5	7.7	29.9	13.9	31.4	4.40	16.1	6.0	6.99
X-67-2	12.7	6.9	31.9	13.8	30.9	4.49	13.9	6.3	7.22
X-67-3	13.1	6.7	29.1	18.0	31.2	4.34	16.7	6.2	7.11
X-26-1	8.0	6.1	29.9	21.2	30.6	4.40	15.2	6.4	7.12
X-67-5	12.1	6.7	31.7	14.6	31.7	4.34	14.2	5.3	6.09
X-146-1	17.3	7.4	28.0	16.1	31.2	4.26	13.4	4.9	5.61
X-26-2	5.8	6.6	29.1	16.1	31.3	4.57	13.9	6.0	6.78
X-67-4	11.3	6.8	29.7	17.1	31.4	4.38	15.2	6.1	7.03
Rutgers	12.4	7.0	34.1	17.0	32.2	4.43	14.4	5.9	6.98
X-26-3	8.5	7.0	34.9	18.0	31.8	4.48	14.5	6.0	6.83
L.S.D. @ 5%	1.6	n.s.	n.s.	n.s.	0.09	n.s.	n.s.	0.5	0.57

Table 4.—Quality of processed tomatoes and tomato juice of nine advanced breeding lines at Salisbury, Md., 1954. (Sampling dates: August 11, August 26, September 2.)

Line	Canned juice					Canned tomatoes			
	Color U.S.	pH	Percent- age of solu- ble solids	Viscosity (seconds)	Percent- age of separa- tion	Color (U.S.)	Percent- age of drained weight	Whole- ness (1-10)	Firm- ness (1-10)
X-67-1	26.6	4.33	6.5	13.6	4.3	23.5	72.0	6.6	6.6
X-67-2	25.7	4.46	6.7	13.0	3.3	23.6	74.4	7.3	6.6
X-67-3	25.9	4.35	6.6	14.6	2.2	24.9	68.2	5.0	4.6
X-26-1	26.2	4.40	6.9	12.8	2.3	24.6	71.5	5.6	5.3
X-67-5	27.6	4.31	6.1	12.9	3.0	24.7	74.2	7.3	8.0
X-146-1	27.3	4.27	5.5	12.0	5.7	26.8	72.9	5.3	6.3
X-26-2	26.2	4.55	6.3	14.0	0.7	23.6	71.1	5.0	5.0
X-67-4	27.3	4.35	6.7	13.0	2.7	24.4	69.8	6.0	5.0
Rutgers	27.1	4.45	6.5	13.8	1.7	24.5	70.0	6.3	6.3
X-26-3	26.9	4.45	6.6	13.5	2.2	24.8	74.8	5.3	5.3
L.S.D. @ 5%	n.s.	0.04	0.5	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

in the canned juice. Tendency toward separation seemed to increase at the high level of nitrogen, the medium level of phosphorus, and the medium and high levels of potassium. In the study reported herein nine different fertilizer treatments were used. In all plots 500 pounds of 5-10-10 per acre were applied and plowed in early spring. The check plots did not receive any additional fertilizer, while in the other plots the plants were side-dressed with their respective treatments when the crown-set was half grown. These eight treatments were as follows: Nitrogen at 100 and 200 pounds per acre; P_2O_5 at 200 and 400 pounds to the acre; K_2O at 100 and 200 pounds per acre; and MgO at 80 and 160 pounds per acre. The purpose of the experiment was to find the effect of these nutrient elements on quality when applied at levels above and beyond those required for maximum yields.

The results are presented in Tables 5 and 6. Similar to the results obtained from the previously mentioned study, the different treat-

Table 5.—Effects of fertilizers on yield and quality of raw tomatoes, 1954.
(Sampling dates: Weekly from August 4 to October 12.)

Treatment	Yield (T/A)	Firm- ness (1-10)	Per- cent- age of waste	Percent- age of trim- ming loss	Color (U.S.)	pH	Vis- cosity (sec- onds)	Percentage of	
								Solu- ble solids	Total solids
Check 500 lbs 5-10-10 plowed.....	16.8	7.2	33.5	17.2	28.3	4.39	15.2	5.6	6.54
Check + 100 lbs/acre N....	16.6	7.5	29.8	18.0	28.3	4.38	19.1	5.7	6.68
Check + 200 lbs/acre N....	15.6	7.5	29.7	17.6	27.9	4.35	17.5	5.7	6.68
Check + 200 lbs/acre P ₂ O ₅ ...	18.2	7.2	30.3	17.2	28.2	4.37	17.9	5.6	6.54
Check + 400 lbs/acre P ₂ O ₅ ...	18.7	7.3	30.3	18.8	28.3	4.36	15.7	5.8	6.57
Check + 100 lbs/acre K ₂ O...	17.5	7.7	29.3	17.8	28.2	4.37	16.3	5.6	6.46
Check + 200 lbs/acre K ₂ O...	19.2	7.7	30.3	17.6	27.9	4.35	15.2	5.6	6.40
Check + 80 lbs/acre MgO.....	17.9	7.4	29.7	17.0	28.1	4.36	15.8	5.5	6.23
Check + 160 lbs/acre MgO.....	16.9	7.7	30.0	18.0	27.8	4.34	16.0	5.6	6.34
L.S.D. @ 5%.....	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.2	n.s.

Table 6.—Effects of fertilizers on quality of processed tomatoes and tomato
juice, 1954. (Sampling dates: Weekly from August 4 to October 12.)

Treatment	Canned juice					Canned tomatoes			
	Color (U.S.)	pH	Percent- age of soluble solids	Viscosity (seconds)	Percent- age of separa- tion	Color (U.S.)	Percent- age of drained weight	whole- ness (1-10)	firm- ness (1-10)
Check 500 lbs. 5-10-10 plowed	24.9	4.43	5.8	12.7	7.7	24.3	80.7	7.5	7.2
Check + 100 lbs/acre N.....	24.9	4.41	5.8	13.2	5.5	22.7	77.7	6.3	6.1
Check + 200 lbs/acre N.....	24.8	4.37	6.0	13.1	5.9	22.0	77.5	5.8	5.5
Check + 200 lb/acre P ₂ O ₅ ...	24.4	4.38	5.8	12.8	6.3	22.7	80.4	6.8	6.2
Check + 400 lbs/acre P ₂ O ₅ ...	25.1	4.37	5.9	12.6	6.6	23.6	76.3	5.2	4.9
Check + 100 lbs/acre K ₂ O...	24.7	4.37	5.8	12.8	7.3	23.9	80.3	5.7	5.8
Check + 200 lbs/acre K ₂ O...	24.6	4.37	5.8	12.5	7.7	23.0	78.1	6.0	5.9
Check + 80 lbs/acre MgO...	24.9	4.37	5.5	12.1	7.7	22.1	77.7	7.2	6.9
Check + 160 lbs/acre MgO...	24.6	4.36	5.7	12.5	8.8	23.8	78.0	6.4	6.2
L.S.D. @ 5%.....	n.s.	n.s.	n.s.	n.s.	2.4	n.s.	n.s.	n.s.	n.s.

ments did not affect the yield or quality except in two instances. When compared with the check, the high level of phosphorus resulted in a higher percentage of soluble solids in the raw juice. This difference, however, was rather small and was not detected in the canned juice, probably due to the uncontrolled evaporation that took place during the preheating process. Comparing the effects of the various treatments on the degree of separation in the canned juice, it may be seen in Table 6 that the application of the high

level of magnesium resulted in the highest percentage of separation, whereas with the two levels of nitrogen and the low level of phosphorus separation was lowest. There was always a higher degree of separation with the higher of the two levels of each of the four nutrients. These differences, however, were not significant; furthermore, when compared with the check, which represented the lowest level of these nutrient elements, such relationships did not exist. Thus, under the conditions of this study these four nutrient elements did not affect the quality of the tomato fruit to any significant extent. Contradictory results by other workers (7, 8) may hold true in a comparison of optimum and deficiency levels; however, this was not the objective of this study. The results obtained by Jones and Warren (9) clearly indicate that late applications of phosphorus were ineffective, which is in agreement with the results reported herein.

Effect of Foliar Nutrient Sprays. This study was conducted with the objective of investigating the effect of magnesium, calcium and boron when applied as a foliar spray in conjunction with the customary zinc ethylene bisdithiocarbamate (ZINEB) spray program. Ten different treatments were applied in this test. The check plots were sprayed weekly with ZINEB starting from the time the crown-set fruits were approximately half grown. The other nine treatments were applied either weekly with the fungicidal spray or only twice—when the crown-set was half grown and again after the third harvest. Magnesium was applied either as MgSO_4 or chelated, calcium in the chelated form, and boron as $\text{Na}_2\text{B}_4\text{O}_7$. The various treatment combinations and frequencies, along with the data, are presented in Tables 7 and 8. The only outstanding result obtained from this test was the effect of chelated calcium on retention of color during processing. The data presented in Table 8 indicate that application of chelated calcium twice during the season at 2 pounds per acre resulted in superior color of canned juice and tomatoes as compared with the check. This difference, however was not detected in the color of the raw pulp, thus indicating an advantageous effect of calcium on retention of color against thermal destruction, rather than its effect on the development of the pigment. More work is needed in this field, especially in regard to the possible effect of calcium on the thermal destruction of the lycopene molecule (17). Calcium supplied as a foliar spray was reported by Evans and Troxler (4) and later in an unpublished report by C. M. Geraldson to correct localized calcium deficiency in the tomato fruit and to control blossom-end rot. Geraldson also reported that a continuous spray schedule with calcium chloride is injurious to the plants. The weekly application of the combinations of the high levels of chelated calcium and chelated magnesium proved to be definitely injurious and resulted in surface defects on the fruits. A possible criticism of this test was the use of the chelated calcium and magnesium mixed with the zinc containing fungicide. In such a mixture undetected replacements might have occurred due to the higher chelating priority of zinc as compared, for example, with magnesium.

September 24.)

[illegible]

Table 8.—Effects of nutrient sprays on quality of processed tomatoes and tomato juice, 1954. (Sampling dates: August 11, August 26, September 2, September 24.)

Treatment in addition to a weekly spray of ZINEB	Canned juice			Canned tomatoes		
	Color (U.S.)	pH	Percentage of soluble solids	Viscosity (seconds)	Percentage of separa- tion	Firmness (1-10)
None.....	24.9	4.51	5.7	11.2	4.6	6.8
MgSO ₄ (4 lb/A) + B (2 lb/A) 2 sprays.....	25.5	4.48	5.6	11.6	2.1	7.0
Chelated Ca (10 lb/A) weekly.....	24.5	4.52	5.6	11.3	3.6	5.8
Chelated Ca (10 lb/A) 2 sprays.....	25.7	4.51	5.5	11.4	3.5	5.3
Chelated Ca (2 lb/A) 2 sprays.....	26.0	4.51	5.6	10.9	3.5	5.8
Chelated Mg (10 lb/A) weekly.....	25.6	4.52	5.6	11.4	2.6	4.3
Chelated Mg (10 lb/A) 2 sprays.....	25.5	4.49	5.5	11.6	2.5	5.8
Chelated Mg (2 lb/A) 2 sprays.....	25.7	4.46	5.5	11.8	4.4	5.0
Ca + Mg chelates (10 lb/A) weekly.....	24.0	4.52	5.5	11.0	3.6	4.0
Ca + Mg chelates (10 lb/A) + B (2 lb/A) 2 sprays.....	24.8	4.48	5.6	11.1	3.7	6.0
L.S.D. @ 5%.....	1.0	n.s.	n.s.	n.s.	n.s.	n.s.
					1.1	n.s.

Effect of Time of Planting. One of the foremost difficulties encountered in the production of well-colored tomatoes in Maryland is related to the fact that the bulk of the crop ripens during the high temperatures of August. Thus one of the objectives of this study was to examine the possibility of shifting the peak of harvest beyond the hottest part of the summer by delaying the date of planting. Five-week-old plants of the Rutgers and Chesapeake varieties were planted in the field on each of three successive dates: May 7, May 17, and June 1. The data obtained from this study are presented in Tables 9, 10, and 11.

The significant interaction results from the reaction of the two varieties to the delay in planting. The marketable yield of Chesapeake was sharply reduced as planting was delayed, with a difference of 4.1 tons per acre between the first two dates and 4.6 tons between the second and third dates. This steep descent was not observed in Rutgers, which showed a decline of 2.3 tons only at the third planting date—actually less than the difference required for statistical significance. Specificity of Chesapeake to the length of the growing season, and to the type of soil, may be of great importance

Table 9.—Effect of planting date on the total marketable yields of Chesapeake and Rutgers tomatoes. (Tons per acre)

Variety	Planting dates			Average
	May 7	May 17	June 1	
Chesapeake.....	15.8	11.7	7.1	11.5
Rutgers.....	11.8	11.9	9.6	11.1
Average.....	13.8	11.8	8.4	
L.S.D. 5% level	For planting date—2.0			
	For interaction —2.9			

Table 10.—The influence of date of planting in 1954 on yield and quality of raw tomatoes.

Variable	Firmness (1-10)	Percent- age of waste	Percent- age of trimming loss	Color (U.S.)	pH	Viscosity (seconds)	Percent- age of soluble solids	Percent- age of total solids
Variety								
Chesapeake..	7.5	29.1	17.0	28.1	4.32	15.8	5.5	6.32
Rutgers.....	7.6	29.4	19.8	29.6	4.34	16.2	5.4	6.13
L.S.D. @ 5%	n.s.	n.s.	2.0	0.8	n.s.	n.s.	n.s.	n.s.
Date of planting								
May 7.....	7.3	29.7	17.4	29.0	4.36	16.3	5.5	6.36
May 17.....	7.4	28.8	19.6	29.1	4.34	15.5	5.4	6.16
June 1.....	8.0	29.2	18.6	29.2	4.30	16.2	5.4	6.15
L.S.D. @ 5%	0.5	n.s.	n.s.	n.s.	0.03	n.s.	n.s.	n.s.
Date of sampling								
August 17....	8.2	29.1	20.8	30.0	4.36	14.5	6.5	7.03
August 24....	6.9	31.4	15.4	30.0	4.42	15.3	6.5	6.60
August 31....	7.7	32.3	16.6	30.7	4.32	16.0	5.6	6.03
September 14	7.3	26.8	20.8	29.0	4.38	19.4	5.3	6.22
September 21	7.8	30.0	16.0	27.6	4.29	16.6	5.3	6.03
September 28	7.6	25.9	21.4	29.5	4.23	14.2	4.4	5.45
L.S.D. @ 5%	n.s.	3.1	1.7	1.7	0.05	2.1	0.5	0.5

Table 11.—The influence of date of planting in 1954 on quality of processed tomatoes and tomato juice.

Variable	Canned juice					Canned tomatoes			
	Color (U.S.)	pH	Percent- age of soluble solids	Vic- cosity (seconds)	Percent- age of separa- tion	Color (U.S.)	Percent- age of drained weight	Whole- ness (1-10)	Firm- ness (1-10)
Variety									
Chesapeake...	26.4	4.37	5.7	13.1	3.4	24.0	74.0	5.7	5.5
Rutgers.....	27.0	4.38	5.6	13.2	3.1	25.0	70.7	5.9	5.3
L.S.D. @ 5%	0.5	n.s.	n.s.	n.s.	n.s.	1.0	2.7	n.s.	n.s.
Date of planting									
May 7.....	26.8	4.37	6.0	13.0	4.7	23.5	72.5	5.9	5.5
May 17.....	26.4	4.41	5.6	13.0	2.4	25.2	72.6	5.4	5.2
June 1.....	26.6	4.36	5.3	13.4	2.7	24.9	72.1	6.1	5.5
L.S.D. @ 5%	n.s.	n.s.	0.2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Date of sampling									
August 17....	27.3	4.42	6.4	12.3	5.7	25.9	64.2	3.0	2.7
August 24....	26.7	4.40	6.2	11.9	4.0	25.0	76.8	7.8	7.2
August 31....	27.7	4.43	5.6	11.2	8.2	25.2	75.2	6.3	5.8
September 14.	26.1	4.41	5.6	14.8	0.7	23.4	73.8	5.8	5.7
September 21.	25.5	4.34	5.2	13.8	1.0	22.8	71.4	6.3	5.7
September 28.	26.6	4.27	4.7	14.8	0.0	24.9	72.8	5.5	5.5
L.S.D. @ 5%	0.9	0.6	0.3	1.1	2.8	1.8	4.6	1.7	1.6

in determining its adaptation. Unfortunately, the peak of harvest was not affected by delaying planting, which is in agreement with results reported by Larson and Pollack (14). The harvest season of the delayed plantings started later and ended sooner than the earlier plantings. Thus under the climatic conditions which prevailed in this area, the peak of tomato production could not be shifted economically by varying planting dates.

The data pertaining to determinations of quality are presented in Tables 10 and 11. Only the main effects are presented inasmuch all the interactions were insignificant. A comparison of the color of the raw and processed products shows that Rutgers was always superior to Chesapeake. Chesapeake, however, gave a higher drained weight and less trimming loss than Rutgers. In both varieties, the raw tomatoes of the third planting were firmer than those of the earlier two plantings. The delay in planting resulted in an increase in acidity of the raw product, as indicated by the pH values presented in Table 10. It was also observed that the soluble solids in the canned juice decreased with the delay in planting. These differences in pH and soluble solids, however, were rather small and did not prove to be consistent when comparing the raw and canned juices. Most of the results were in accord with the findings from the unpublished 1953 experiments.

The lower portions of Tables 10 and 11 present the quality of six successive pickings. In almost every aspect of quality, tomatoes from the various pickings were significantly different. Firmness of the raw fruits was the only exception. In most cases the differences between the various harvest dates were erratic and did not form any specific pattern. This may possibly point to the fact that the climatic conditions preceding each harvest were largely responsible. On the other

hand, soluble solids, total solids, and pH followed a definite trend, each continuously decreasing during the season, indicating that the climatic effect was masked by the physiological age of the plants and their nutritional status. This is in agreement with the work of Scott and Walls (20), who found a general inverse relationship between the sugar content and the total acidity in 13 different varieties; and with the work of McCollum (19), who found that in different grades of tomato juice the decrease in pH was paralleled to the decrease in total soluble solids. Forshey and Alban (5) also reported that reducing sugars decreased with each successive picking of greenhouse tomatoes during the fall and suggested that this may be due to restricted photosynthetic activity caused by the decreasing day length. Similarly, in the present study the descending trend of the soluble solids could be attributed to decreasing day length and to the decreasing vegetative vigor of the plants as they approach the end of the season. The effect of the date of planting on soluble solids could be similarly explained inasmuch as the plants of the later

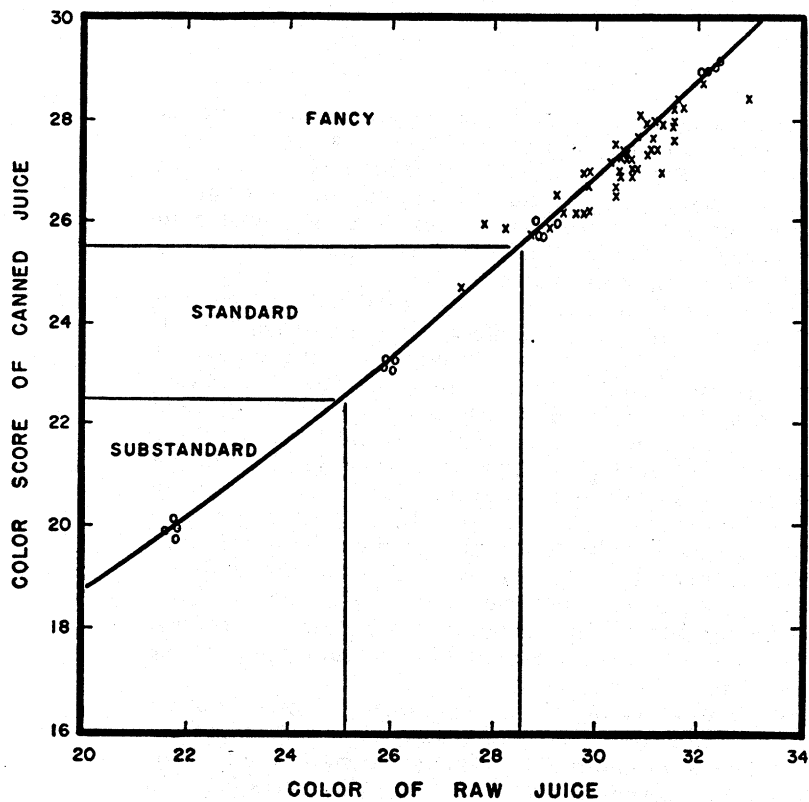


Fig. 1. Relation of color score of raw tomato juice to the canned juice. The values are equivalent to U. S. grade scores for the color factor. o = values reported by Kramer and Ogle (11). x = values obtained in this study.

date flowered and set fruits at a less vigorous vegetative stage, and were always less vigorous than plants set the earlier date, which is in accord with findings reported by Larson and Pollack (14).

In these studies optimum fertility levels and ideal cultural practices were maintained.

Color Relationships in Raw and Processed Products. Figs. 1 and 2 illustrate the relationship between the color of the raw pulp and that of the processed juice and that of whole tomatoes, over the three year period. An excellent positive correlation of .9209 was obtained between the color of the raw pulp and the color of the canned juice, as shown in Fig. 1. This relation of color of raw to processed juice follows very closely the one established previously by Kramer and Ogle (13), as shown in Fig. 1. The juice reported in this study was all sterilized at 212 degrees F for 20 minutes. It has been previously reported by Kramer and Kattan (12) that as long as a thermal sterilization value (F_0) of 0.7 was maintained, the differences in color loss resulting from the use of different sterilization temperatures are rather small and of little practical importance.

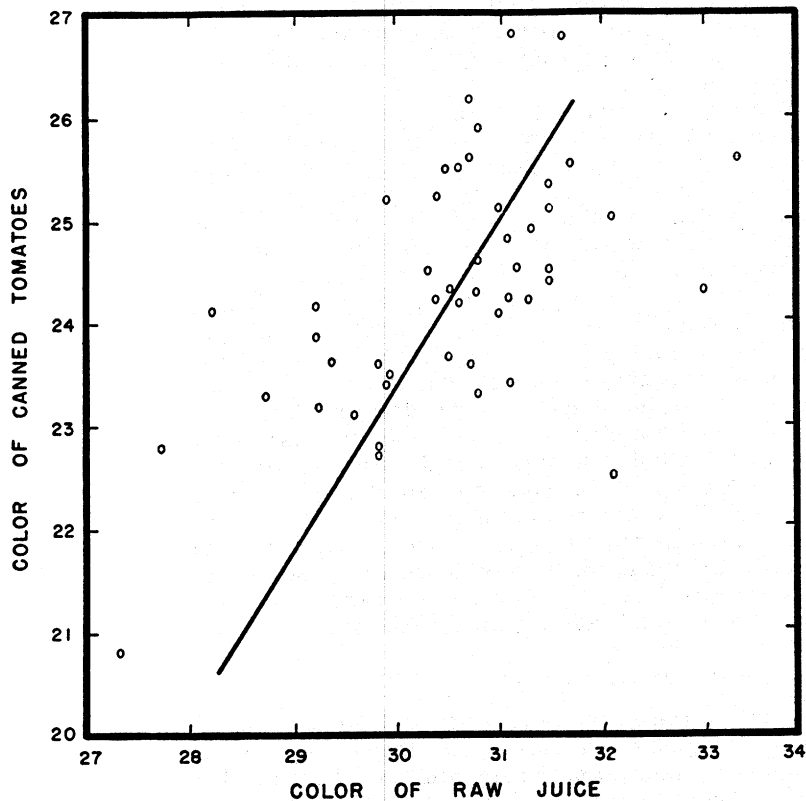


Fig. 2. Relation of color score of raw tomatoes to canned whole tomatoes. The values are equivalent to the U. S. score for the color factor.

The values presented in Table 12 were obtained from the solid regression line shown in Fig. 1, which fits the data reported previously (13) as well as the results obtained in the present study.

Table 12.—Relationship between the color of the raw pulp and the canned tomato juice. (U. S. Color Grade Score)

Fancy			Standard			Substandard		
Raw	Processed	Loss	Raw	Processed	Loss	Raw	Processed	Loss
33	29.8	3.2	28	25.0	3.0	24	21.6	2.4
32	28.8	3.2	27	24.1	2.9	23	20.9	2.1
31	27.8	3.2	26	23.2	2.8	22	20.1	1.9
30	26.9	3.1	25	22.6	2.6	—	—	—
29	26.0	3.0	—	—	—	—	—	—

In agreement with results of MacGillivray (15), who reported a greater color loss for products whose original color was superior, these studies show a fairly constant loss of approximately three grade points (for this particular heat processing treatment) for tomatoes in the fancy and high standard quality range, and a reduction in color loss for material of poorer color quality. Thus at the standard-substandard level, there is a difference of only approximately 0.7 grade score points in the canned juice for every 1.0 color difference in the unheated fresh pulp.

A positive correlation of 0.6211 was obtained between the color of the raw pulp and the color of the processed tomatoes. Although this coefficient is significant at the 1 per cent level, it is not high enough to justify the calculation of a forecasting equation. This relationship is presented in Fig. 2 along with the linear regression line. The low correlation coefficient and the dispersion of the data could be attributed to two factors. The raw and processed samples for juice studies were both obtained from the same batch; this could not be done in the case of canned tomatoes. Furthermore, color in canned tomatoes was determined following determination of the drained weight. During this determination various amounts of pigment seeped out of the fruits along with the draining liquid. A comparison of Fig. 1 and 2, indicates that color retention was better in the juice than in the whole tomatoes, which is in accord with previous findings by Elehwany (3). This may result from the fact that the outer tissues of the whole fruit are in immobile and constant contact with the retort temperature for a long time and with thermal convection limited to only the liquid portion in the can. These outer tissues accordingly are subjected to a more severe treatment as compared with the juice, where the rate of heat distribution is greater.

SUMMARY AND CONCLUSIONS

The quality of the processed tomato products did not seem to be related to any fertility factors, and a rather wide range of application of nitrogen, phosphorous, potassium, magnesium, and boron failed to exert any significant effects on the quality of the fruits. This statement should by no means detract from the importance of following

the recommended cultural practices and the maintenance of vigorous and disease-free foliage (15), but rather excludes the possibility that a luxurious consumption of any of these elements may improve quality.

Climatic conditions during harvest and the inherited varietal characters were found to be the main factors affecting or contributing to quality, as indicated by the highly significant differences in almost every aspect of quality, found to exist between harvests of different dates. It was not possible to shift the peak of harvest by varying the date of planting within economical limits, and thus the quality of a substantial part of the tomato crop in this area is limited by the high temperatures of August. Irrigation seems to be the only feasible environmental control measure and some of the reported results (1) are encouraging.

Although none of the varieties under study surpassed Rutgers in color, consistent varietal differences are indicative of the inheritance of color intensity. A few varieties, including Chesapeake, were superior to Rutgers from the standpoint of the drained weight percentage, and may be of significant importance to the canner of whole tomatoes. In reality, the major portion of color and firmness improvement remains in the hands of the breeder, and it is hoped that objective quality measurements will be used in the final stages of indexing the adaptation of new selections for processing.

There was beneficial effect of chelated calcium sprays on retention of color. Foliar sprays of magnesium or boron did not exert any measurable effect on quality. Further work is needed before an explanation of the basic function of calcium, in color retention, can be attempted.

The relationships between the color of the raw product and the color of the canned juice and tomatoes were discussed, and the calculated prediction curve may be of some value to the tomato processor in forecasting the quality of the finished product.

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